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MEMORANDUM REPORT

for the

Materiel Division, Army Air Corps

SPIN TESTS OF A 1/20-SCALE MODEL OF THE BELL XP-39E AIRPLANE

By A. I. NEIHOUSE and J. W. KLINAR

Langley Memorial Aeronautical Laboratory

February 9, 1942

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INTRODUCTION

In accordance with the request of the Materiel Division, Army Air Corps, as contained in their letter to the NACA, dated August 11, 1941, tests were performed to determine the spin characteristics of a 1/20-scale model of the Bell XP-39E airplane. The effects of control dispositions were investigated, and brief tests were made with the mass distribution and center-of-gravity location varied moderately. The effect of installing an external 614-pound demolition bomb was determined, as was also the effect of modifying the tail. The results of the investigation are presented in this report.

APPARATUS AND MODEL

The tests were performed in the NACA new 20-foot free-spinning wind tunnel, the operation of which is, in general, similar to that of the old 15-foot tunnel as described in reference 1.

The 1/20-scale model was furnished by the Materiel Division and was built from Bell drawings 23-943-017, 23-943-018, 23-943-019, 23-943-020, 23-943-021, 23-943-022, and 23-943-024. The dimensions of the model were not checked by the NACA, but were assumed to be in accordance with the drawings. The weight, moments of inertia, and center-of-gravity location used in ballasting the model were obtained from Bell Report No. 23-942-003, and the length and location of the mean aerodynamic chord were obtained from Bell Report No. 23-942-001.

A remote-control mechanism was installed in the model by the NACA to actuate the controls for recovery tests. Lead ballast was placed at suitable locations in order to bring the weight, moments of inertia, and center-of-gravity position to the desired values. The model was equipped with tricycle landing gear which was independently ballasted so that the proper changes in mass distribution would result when the wheels were extended. The model was also equipped with split trailing-edge flaps which were deflected for the landing condition.

The current airplane differed dimensionally from previous airplanes of the P-39 series mainly in that the wings and tail surfaces of the XP-39E airplane had square tips in plan form. Fuel tanks, guns, and ammunition were installed along the wings, and as an alternate loading,

a 614- or 306-pound demolition bomb could be carried externally under the fuselage.

Photographs of the model are shown in figure 1. Figure 2 shows the model as tested with a modified tail arrangement.

TEST CONDITIONS

The normal loading condition corresponded to the following mass distribution of the full-scale airplane with the landing gear retracted:

Weight	8984 pounds
x/c	0.254
z/c	0.138
I_X	6361 slug-feet^2
I_Y	7357 slug-feet^2
I_Z	12,901 slug-feet^2

where

x/c is the ratio of the distance of the center of gravity aft of the leading edge of the mean aerodynamic chord to the mean aerodynamic chord

z/c is the ratio of the distance of the center of gravity below the thrust line to the mean aerodynamic chord

I_X, I_Y, and I_Z are the moments of inertia about the body axes X, Y, and Z, respectively

The model was tested at an equivalent spin altitude of 6000 feet. (ρ = 0.001988 slug per cubic foot.)

The weight and mass distribution of the model were held to the true scaled-down values within the following limits:

Weight . . . . ±1 percent

Center-of-gravity location . . . . ±1 percent MAC

Moments of inertia	I_X	5 percent low to 4 percent high
	I_Y	5 percent low to 8 percent high
	I_Z	3 percent low to 9 percent high

The model was originally ballasted so that the mass characteristics corresponded to the specified normal values within closer limits than indicated above. During the course of testing, however, it proved impractical to keep within the original tolerances.

The following maximum control displacements were obtained from Bell drawing No. 23-976-001.

Rudder . . . . ±25°

Elevator . . . . 25° up, 15° down

Aileron . . . . 25° up, 10° down

Flaps . . . . 45° down

Brief tests were performed to determine the effects of varied moments of inertia and center-of-gravity location upon the general spin and recovery characteristics. In order to obtain these loading variations, provision was made for

redistributing weights along the wings (changing moments of inertia I_X and I_Z), and for redistributing weights along the fuselage (changing the moments of inertia I_Y and I_Z, or changing the center-of-gravity location).

RESULTS

The results of the investigation are presented in charts 1, 2, and 3. The steady-spin parameters presented in the charts were determined by the methods described in reference 1, and have been converted to corresponding full-scale values. Tests were made for both right and left spins and, as the results were found to be in agreement, the data presented are applicable to both. The angle α between the thrust axis and the vertical is taken as the angle of attack. The angle ϕ is the angle between the span axis and the horizontal, and is considered positive when the right wing is down. The angle of sideslip is approximately equal to ϕ minus the helix angle (the angle between the flight path and the vertical). Inward sideslip is considered positive in a right spin. For recorded steady spins, the helix angle was approximately 2° for the flat spins and 4° for the steep ones. V, the rate of descent, is given in feet per second, and Ω, the rate of rotation, is given in revolutions per second.

Recovery turns are measured by the number of turns the spinning model makes from the time the controls are moved until the spinning rotation ceases.

PRECISION

Spin-tunnel results are believed to be the true values given by the model within the following limits:

V	± 2 percent
Ω	± 2 percent
α	$\pm 3^{\circ}$
ϕ	$\pm 1^{\circ}$
Turns for recovery	$\pm \frac{1}{2}$ turn

The preceding limits may be exceeded for certain cases where it is difficult to handle the spin in the tunnel due to the wandering or oscillatory nature of the spin, or to a very high rate of descent. Since, in many instances, the number of turns for recovery was estimated from visual observation rather than from photographic data usually made use of, the limits of accuracy for the number of turns for recovery were raised from the customary $\pm \frac{1}{4}$ turn to $\pm \frac{1}{2}$ turn.

Comparison between model and airplane results (references 1 and 2) indicates that because of scale and tunnel effects, lack of detail in the model, and differences in operators' technique, the spin-tunnel results are not always in complete agreement with full-scale spinning data. In general, for a given loading condition and control setting, the model steady-spin results have shown a somewhat smaller

angle of attack, a somewhat higher rate of descent, and from 5° to 10° more outward sideslip at a given angle of attack. The comparison made in reference 2 showed that 80 percent of the model recoveries predicted satisfactorily the corresponding full-scale recoveries, and that 10 percent underestimated and 10 percent overestimated the full-scale recoveries.

DISCUSSION

Preliminary tests revealed that two conditions of spinning equilibrium were usually possible for the model, one at a low angle of attack and the other at a moderately high angle of attack. Tests with small variations in mass distribution and in control setting indicated that the type of spin obtained was not readily influenced by small aerodynamic or mass changes. Since it was felt that either the flat or the steep spin might be encountered in flight, depending on the method of entry, both types were investigated. For the model tests, variation in the method of launching the model into the tunnel was used as a means of obtaining both types of spins.

Flying Condition

The effect of control setting on the steady-spin and recovery characteristics of the model in the normal flying condition is shown on chart 1. Results are presented for both the flatter and the steeper of the two types of spins obtainable.

For the normal control configuration for spinning (rudder full with, elevator full up, and ailerons neutral), the model spun moderately flat (angle of attack, 56°) when launched in a spin in a flat attitude, and descended at a moderate rate (188 feet per second, full-scale). Recovery by full rapid rudder reversal took place in $3\frac{1}{4}$ turns. For the same control configuration, when the model was launched in a spin in a steep attitude, the ensuing spin was steep, the rate of descent fairly high, and recovery by full rapid rudder reversal took place in $\frac{3}{4}$ turn.

Setting ailerons full against the spin (left aileron up and right aileron down in a right spin) hastened recoveries and led to satisfactory recovery characterisitcs at all elevator settings. Setting ailerons full with the spin affected recoveries adversely at all elevator settings for the flatter type of spin, and had only a slight effect for the steeper type of spin.

Tests made with a 614-pound (full-scale) external demolition bomb installed under the fuselage indicated no appreciable effect upon the general spin and recovery characteristics, and accordingly the condition with the smaller bomb installed was not tested. The results of the tests are not presented in chart form.

Landing Condition

The results obtained for the model in the normal landing condition (landing gear extended and flaps down 45°) are presented on chart 2. For the normal spinning control configuration, the recovery obtained for the flatter type of spin was somewhat slower than that obtained for the flying condition, and, as was the case for the flying condition, ailerons against the spin aided recovery, whereas ailerons with the spin retarded recovery. When the elevator was neutral or down, recovery characteristics were unsatisfactory, regardless of aileron setting.

Steeper spins were also obtainable for the landing condition, and spins were run for the elevator-neutral, aileron-neutral condition, and for the elevator-down, aileron-with condition. From the latter condition, a rapid recovery was obtained by full rapid rudder reversal although no recovery had been obtainable for this control configuration from the flatter spin. This was taken as an indication that all recoveries would be rapid from the steeper type of spin for the landing condition, and accordingly spins with other control configurations were not tested.

Tail Modification

Tests made with vertical area added to the fuselage below the horizontal surfaces and to the rudder as shown in figure 2 indicated that, although flatter and steeper spins were still obtained, there was quite an improvement in the recovery characteristics of the model from the flatter spins. The results indicated that for the model with this modified tail arrangement, recovery by full rapid rudder reversal would not take over $2\frac{1}{4}$ turns in the normal flying condition (chart 3).

COMPARISON OF XP-39E MODEL SPIN CHARACTERISTICS WITH THOSE OF THE P-39D MODEL

The results obtained in the flatter attitude for the XP-39E model were quite similar to that previously obtained for the P-39D model as reported in reference 3. As previously mentioned, however, the XP-39E is also capable of a steeper type of spin. The two models are quite similar in many respects, and although the XP-39E is a slightly larger and heavier airplane, the outstanding difference as concerns spinning seems to be the presence of square tips on the wings and tail of the XP-39E model. It seems likely, therefore, that the steeper type of spin, and subsequent rapid recovery, possible for the XP-39E may be attributable to this factor.

FULL-SCALE SPINS

Available reports on full-scale spin tests of other airplanes indicate that when a spin is entered by the normal method (stick-full-back stall followed by application of full rudder), the initial spin attitude is usually steeper than that corresponding to the final equilibrium condition. For spins of the XP-39E airplane which are entered in the normal manner, the airplane will therefore probably nose down into the steeper of the two types of spins shown by the model to be possible. The flatter type of spin may be obtained, however, particularly when the spin is entered by other methods.

CONCLUSIONS

The model results indicate the following spin and recovery characteristics for the XP-39E airplane:

1. Two types of spin will be possible, one of which will be moderately flat and the other of which will be steep. All recoveries from the steep spins by full rudder reversal will be rapid.

2. In the normal flying condition, for normal spinning control configuration (rudder full with, elevator full up, and ailerons neutral), recovery from the flatter of the two types of spins will be fairly satisfactory if the rudder is reversed fully and rapidly.

3. Setting ailerons full against the spin will generally aid recovery whereas ailerons set full with the spin will retard recovery.

4. For the normal landing condition, recoveries from the flatter type of spin will generally be slow, satisfactory recovery by full rudder reversal being obtained only from the elevator-up, aileron-against spin.

5. Additional fin and rudder area beneath the fuselage in the vicinity of the horizontal tail plane will greatly improve the recovery characteristics of the airplane from the flatter of the two types of spins obtainable.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 9, 1942.

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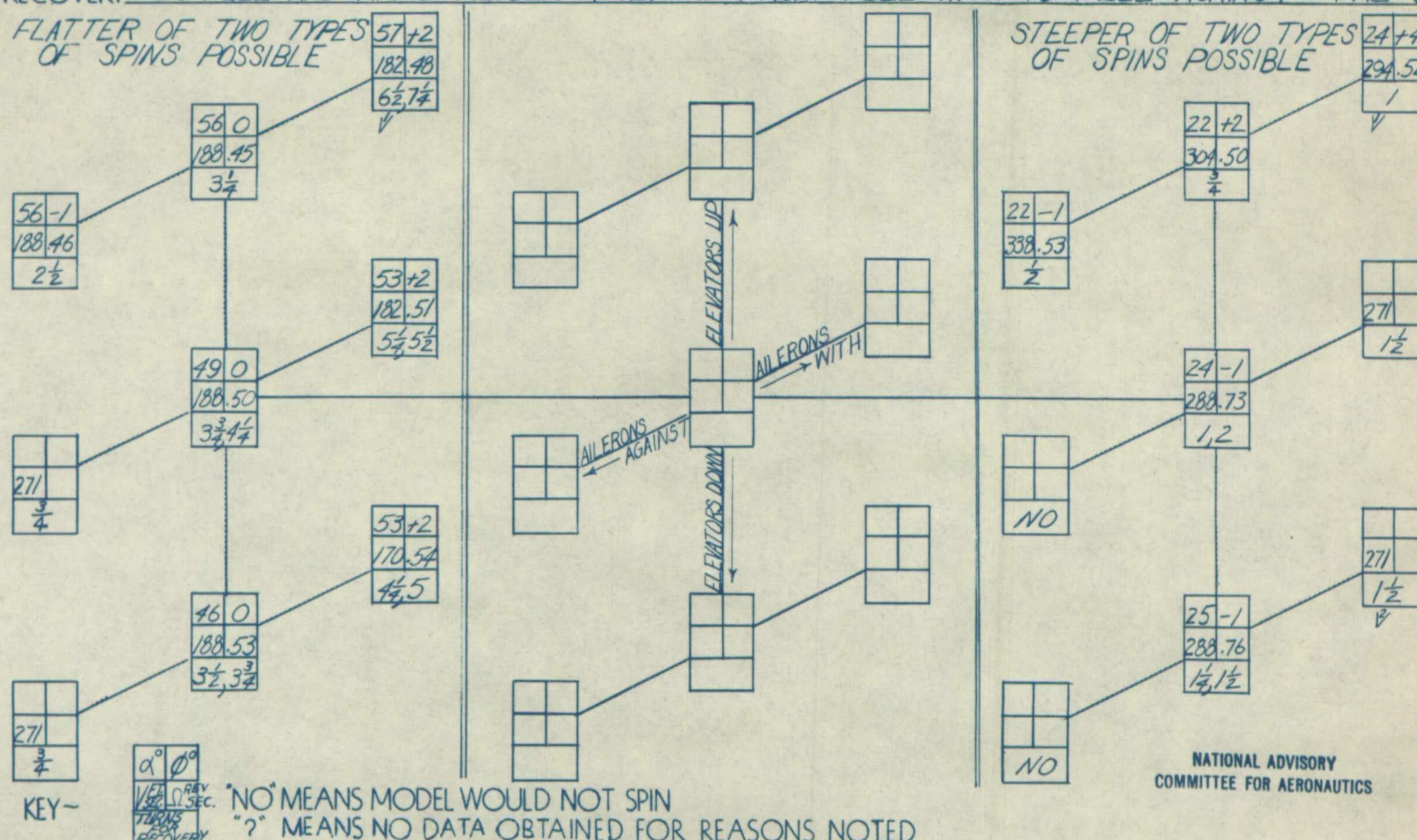
2. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. Conf. Memo. Rep., NACA, Dec. 1938.

3. Kamm, Robert W., and Carmel, Melvin M.: Spin Tests of a 1/20-Scale Model of the Bell P-39D Airplane. Memo. Rep., NACA, Oct. 1941.

CHART I

SPIN CHARACTERISTICS

MODEL XP-39E EFFECT OF CONTROLS LOADING NORMAL COCKPIT CLOSED LANDING GEAR RETRACTED FLAP SETTING NEUTRAL
RECOVERY BY FULL AND RAPID RUDDER REVERSAL FROM FULL WITH TO FULL AGAINST THE SPIN



"NO" MEANS MODEL WOULD NOT SPIN
"?" MEANS NO DATA OBTAINED FOR REASONS NOTED
V WANDERING AND OSCILLATORY SPIN
V GOES INTO AN INVERTED SPIN UPON RECOVERING
STEADY-SPIN DATA IS FOR THE RUDDER-WITH SPINS

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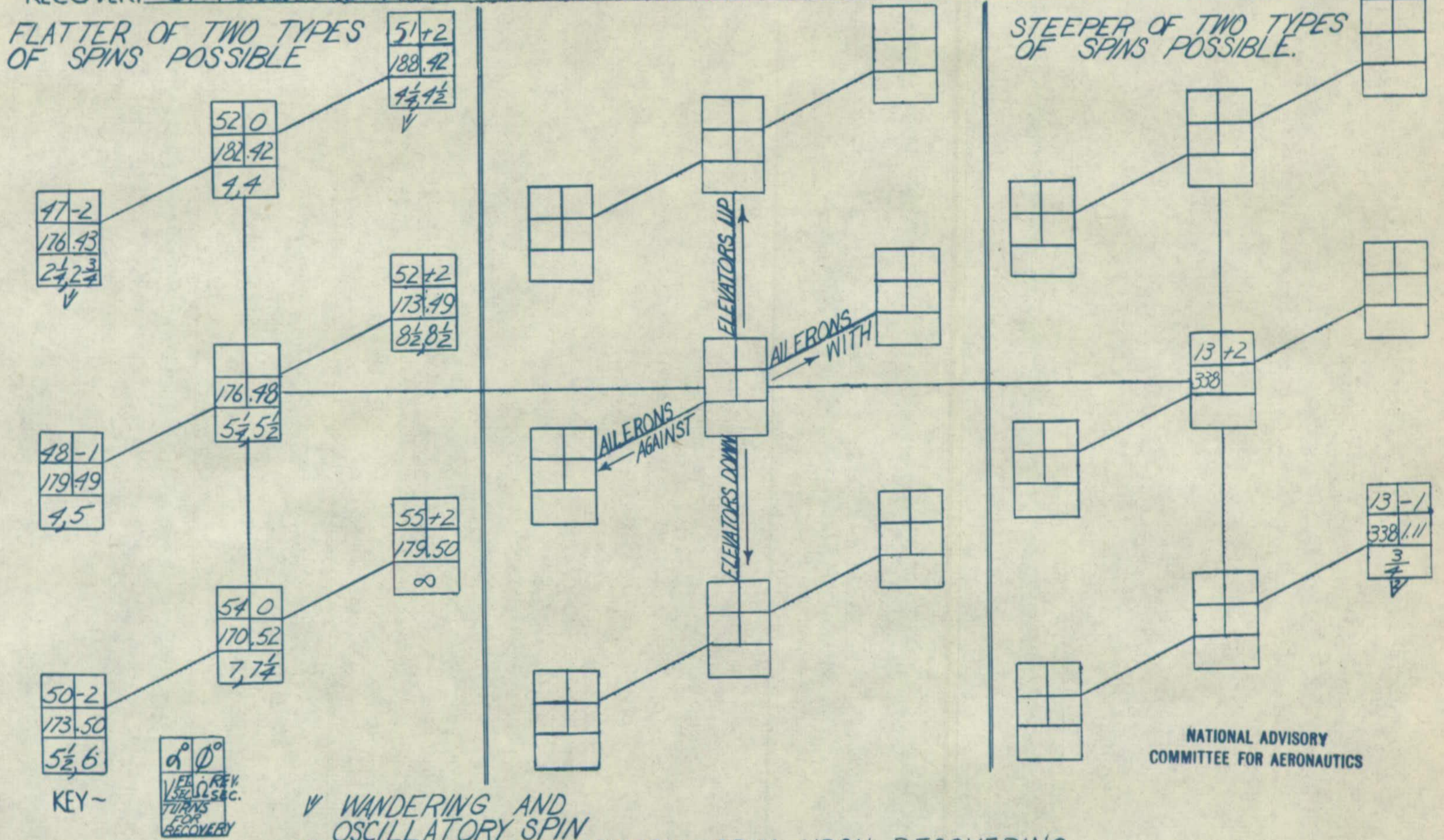
CHART 2

SPIN CHARACTERISTICS

MODEL XP-39E EFFECT OF LANDING CONDITION LOADING NORMAL COCKPIT CLOSED LANDING GEAR EXTENDED FLAP SETTING 45° DOWN
RECOVERY BY FULL AND RAPID RUDDER REVERSAL FROM FULL WITH TO FULL AGAINST THE SPIN



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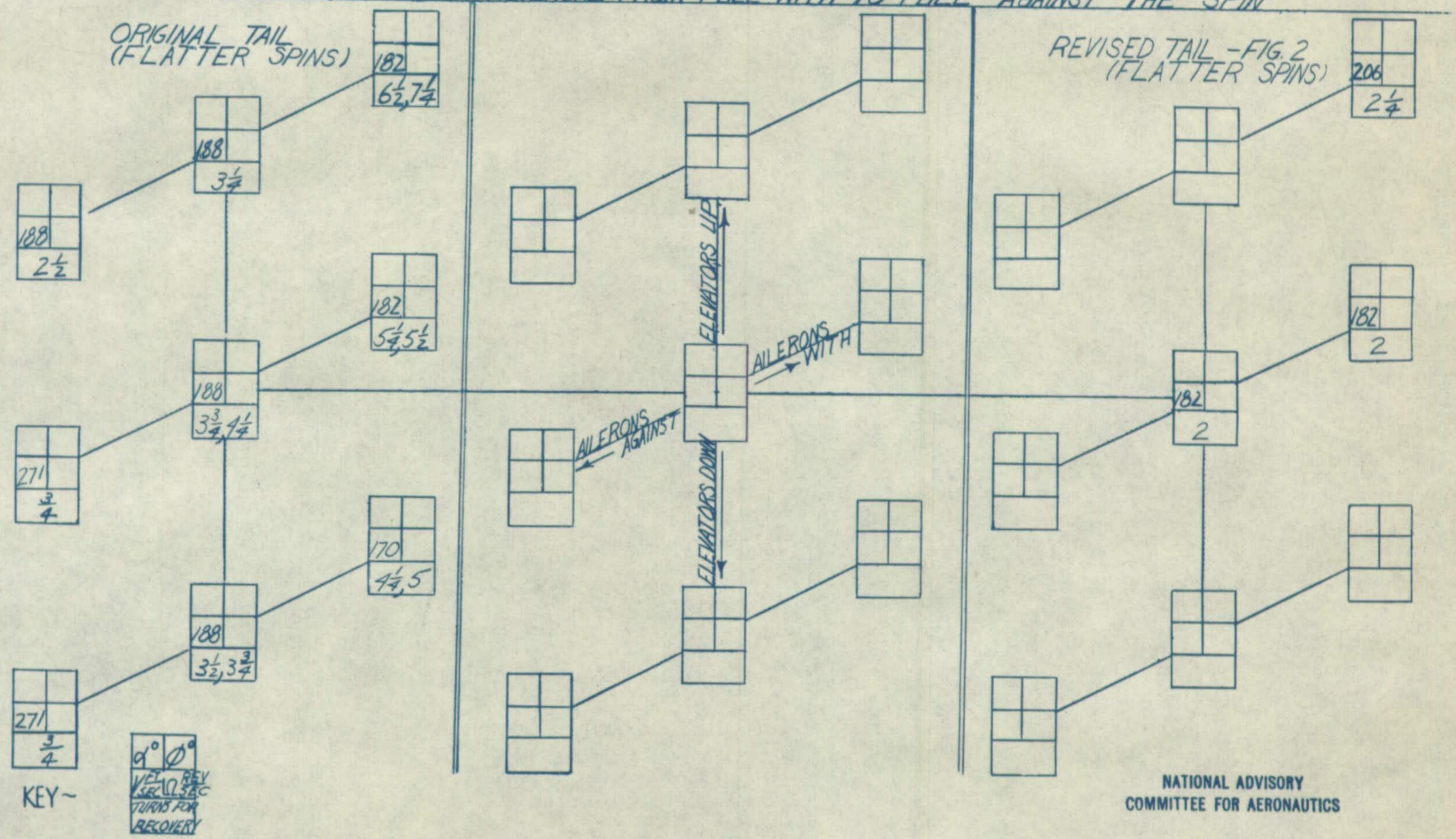
V WANDERING AND OSCILLATORY SPIN
B GOES INTO AN INVERTED SPIN UPON RECOVERING
STEADY-SPIN DATA IS FOR THE RUDDER-WITH SPINS

CHART 3
SPIN CHARACTERISTICS

MODEL XP39E EFFECT OF TAIL MODIFICATION LOADING NORMAL COCKPIT CLOSED LANDING GEAR RETRACTED FLAP SETTING NEUTRAL
RECOVERY BY FULL AND RAPID RUDDER REVERSAL FROM FULL WITH TO FULL AGAINST THE SPIN



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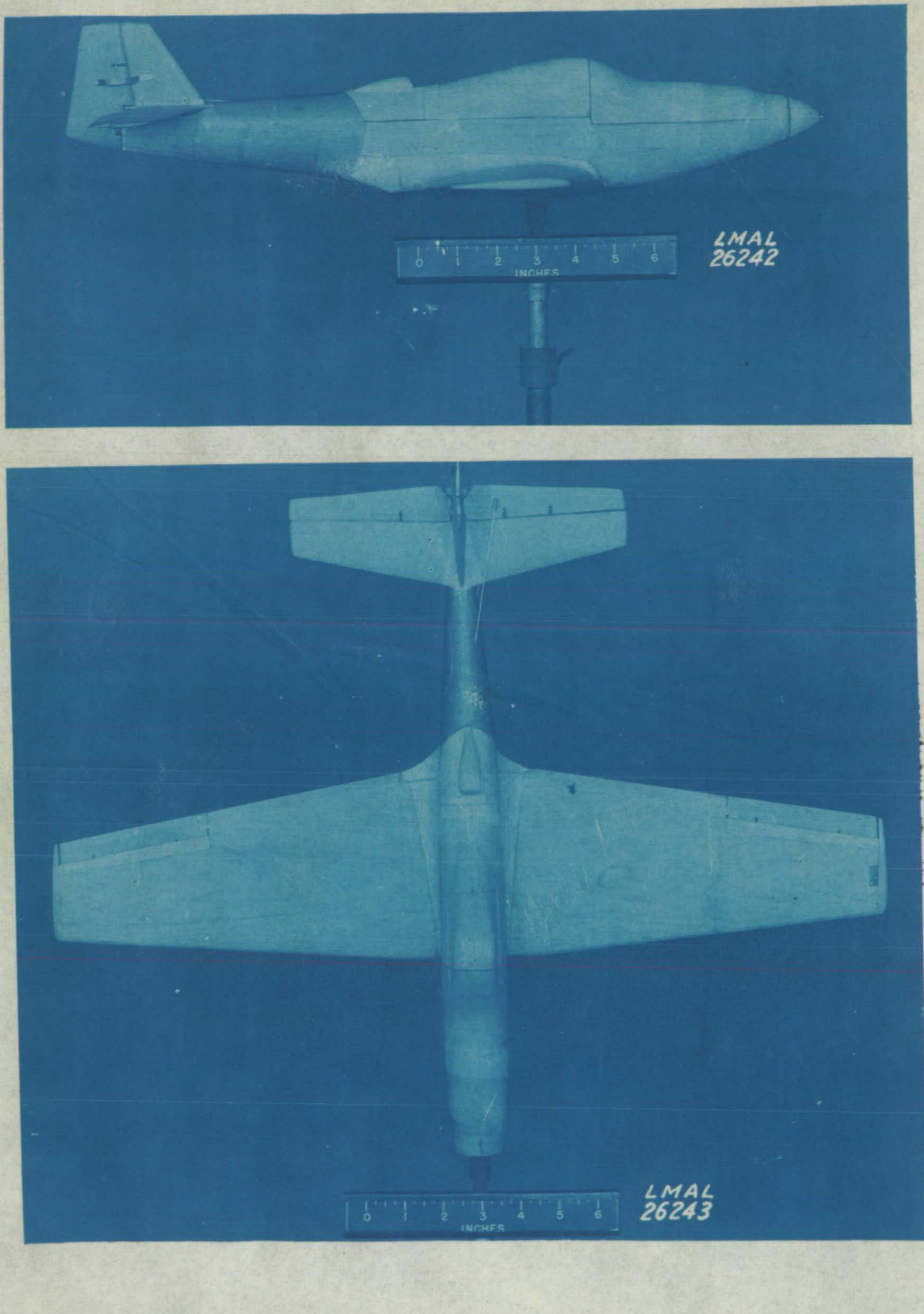

Figure 1.- $\frac{1}{20}$ - scale model of the Bell XP-39E airplane.

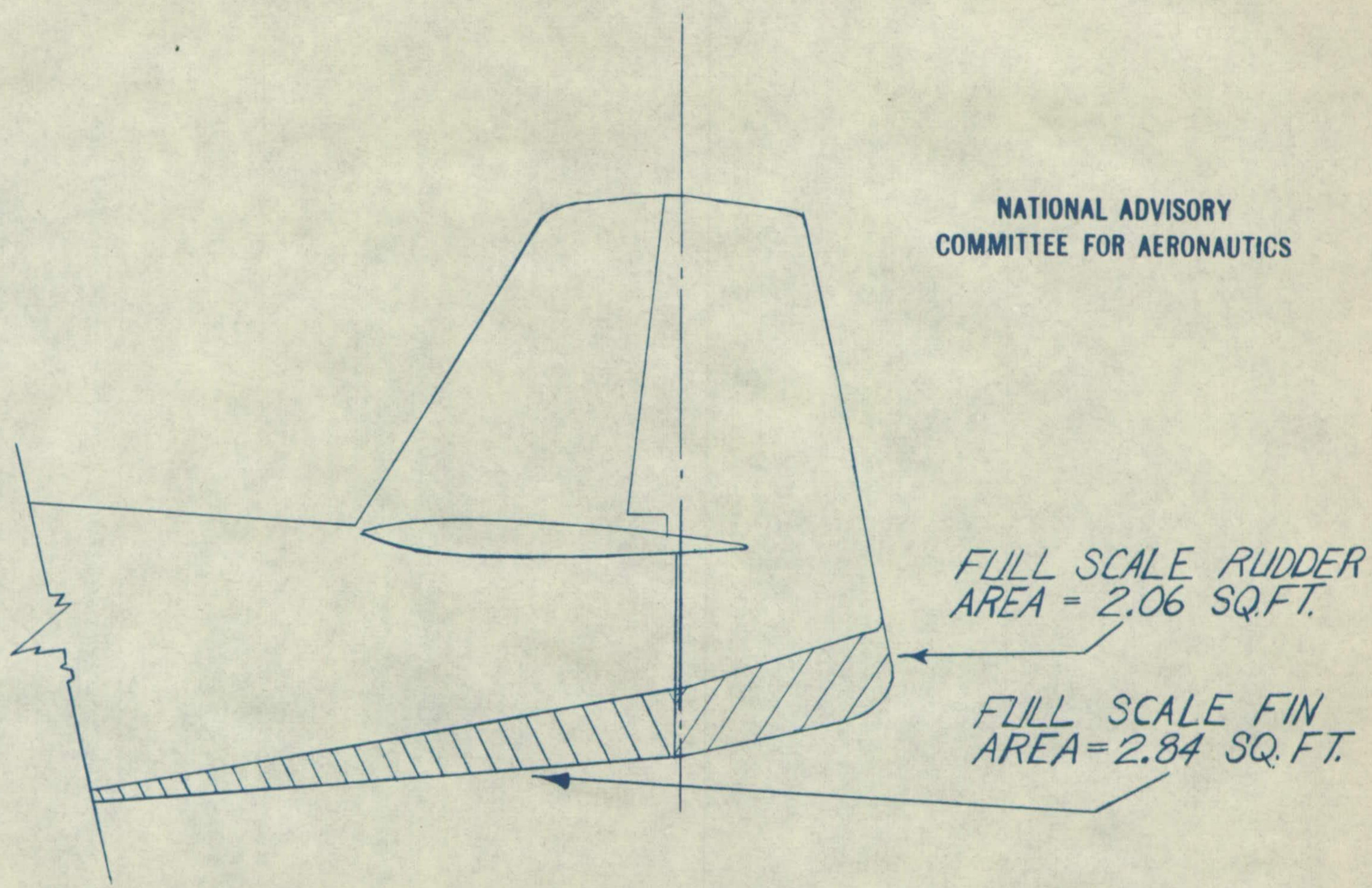

FIGURE 2:- XP-39E TAIL MODIFICATION